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(54) Title: ACRYLIC BASED POWDER PAINT

(57) Abstract

The invention relates to a powder paint based on acrylics. The thermosetting powder paint comprises a hydroxyl functional acrylic resin and an isocyanate crosslinking agent blocked with a blocking agent wherein the isocyanate crosslinking agent is an adduct of an isocyanate and a mixture of polyetramethylene ether glycol and at least one additional, but other glycol, selected from the group consisting of glycols and polyglycols.

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ACRYLIC BASED POWDER PAINT

The invention relates to a powder paint based on acrylics.

The mechanical properties of acrylic based powder coatings are worse (pages 162-167 of "Powder Coatings, Chemistry and Technology" by Tosko Misev; John Wiley and Sons, 1991). Acrylic based powder coatings, which are used in practice, are almost exclusively based on epoxy functional acrylic resins cured with long-chain dicarboxylic acids as hardeners. The long aliphatic chain of the crosslinker provides flexibility and impact resistance to the cured film, but still far below the values which are usually obtainable with the other powder coating systems. In most cases the impact resistance of the acrylic powder coatings does not exceed 30 inch-pounds. This is still several times lower compared to the values of polyester and polyurethane based powder coatings.

It is the object of the invention to provide an acrylic powder coating system which shows excellent hardness, gloss, impact resistance, durability, clearness, chemical resistance and good flexibility.

The invention is characterized in that the thermosetting powder paint comprises

- a hydroxyl functional acrylic resin and
- an isocyanate crosslinking agent blocked with a blocking agent, wherein the isocyanate crosslinking agent is an adduct of an isocyanate and a mixture of polytetramethylene ether glycol and at least one additional, but other glycol, selected from the group consisting of glycols and polyglycols.

Preferably the crosslinker has a melting point higher than 45°C and a molecular weight M_n between 100 and 3000, more preferably between 300 and 1500.

The mixture of glycols and/or polyglycols

contains preferably more than 50% by weight of polytetramethylene ether glycol as one polyol. More preferably this amount is between 60 and 75% by weight.

Suitable other glycols or polyglycols include a great number of diols, triols and polyols, such as for example butanediol, ethanediol, neopentylglycol, 2,2-bis-(1-hydroxy-2-oxyethylphenyl)propane, 1,1-isopropylidene-bis(phenylene-oxy)di-2-propanol-2, cyclohexyldimethylol, trimethylolpropane, trimethylolethane, adipate polyols, polycaprolactone glycols and polycarbonate glycols.

According to a preferred embodiment of the invention the second additional polyglycol is a polyether polyol. A suitable polyether polyol is Voranol 220-530™ (of Dow).

A suitable polytetramethylene ether glycol is Terathane 1000™ (of Du Pont).

Suitable isocyanates include aliphatic (poly)isocyanates such as for example hydrogenated methylene diphenyldiisocyanate (HMDI), isophorone diisocyanate (IPDI), trimer(isocyanate) of isophorone dissocyanate (T1890™, Hüls), 1,6-hexamethylene diisocyanate (HDI) and the trimer of 1,6-hexane-diisocyanate (Tolonate HDT™, Rhone Poulenc), 1,3-bis-(1-isocyanato-1-methylethyl)-benzene (TMXDI; American Cyanamid) or aromatic polyisocyanates, such as for example 2,4 or 2,6-diisocyanatetolueen (TDI) and 4,4'-di-isocyanatediphenylmethaan.

Preferably HMDI is used.

The flexible crosslinker can be prepared by first reacting half of the molar equivalents of an isocyanate with the polyglycol mixture and next reacting the remaining isocyanate equivalent with a blocking agent.

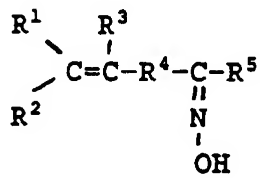
A blocked isocyanate is an isocyanate which has been reacted with a material which will prevent its reaction at roomtemperature with compounds that conventionally react with isocyanates but will permit that reaction to occur at higher temperature.

Blocked isocyanates are described by Wicks in

Progress in Organic Coatings (3, 1975, 73-99).

According to a preferred embodiment of the invention the blocking agent is a non-volatile agent having a polymerisable double bond and an oxime function.

These agents have the general formula (I):



(I)

where

R^1, R^2, R^3= H or (C_1-C_5)alkyl

R^4= aliphatic, amidegroup or organic estergroup and

R^5= (C_1-C_5)alkyl.

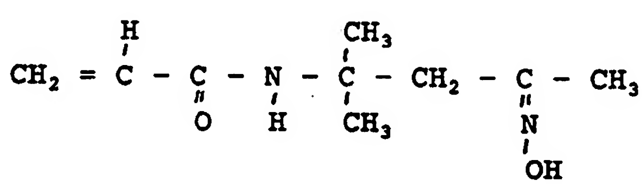
Preferably the amidegroup is steric hindered.

The aliphatic group, preferably, contains 1-10 carbon atoms.

The organic estergroup can be characterized by

$-\overset{\overset{\displaystyle O}{\|}}{C}-O-R^6$ in which $R^6=(C_1-C_{10})$alkyl.

The agent having a polymerizable double bond and an oxime function is preferably an acrylamide derivative having the formula (II):



(II)

This suitable blocking agent according to the invention is diacetoneacrylamide oxime (DAAOX). The preparation of DAAOX is disclosed in Macromolecules, Vol. 16, 10, 1983, pages 1561-1563.

The use of DAAOX and other blocking agents having a polymerisable double bond and an oxime function is very advantageous, because these blocking agents do not evolve during the cure of a hydroxy-isocyanate powder

paint system. The blocking agent can be polymerised during cure of the powder paint, because they consist of a blocking side and a polymerizable double bond. The polymerizable double bond can be polymerized during the cure of the coating by adding a suitable peroxide. Any peroxide having a suitable halflife-time at the curing temperature of the coatings can be used. Preferably the peroxide has a halflife-time of less then 10 minutes at the temperature at which the coating is cured. The amount of peroxide can vary between 0.5 and 4 wt.%, preferably between 1 and 2%, based on the weight of the added blocked isocyanate crosslinker. Suitable peroxides include tert.-amyl-peroxybenzoate, tert.-butylperoxybenzoate and tert.-butylperoxy-2-ethylhexyl carbonate.

Said non-volatile blocking agents can be obtained from compounds having a ketone or aldehyde group which can be converted into an oxime and having an unsaturated double bond as well. Suitable examples of unsaturated ketones or aldehydegroups include methyl-vinyl-ketone, ethyl-vinyl-ketone, mesityl-oxide, allylacetone, crotonaldehyde, 2-hexanal and citronellal. The blocking agent can be reacted with a (poly)isocyanate in a conventional way. Preferably the molar equivalent ratio (poly)isocyanate: blocking agent is substantially 1:1.

The main features of the isocyanate-hydroxyl curing reaction are described in the foregoing cited Powder Coatings, Chemistry and Technology at pages 56-58.

The use of a non-volatile agent having a polymerizable double bond and an oxime function is not limited to the reaction between a blocked isocyanate and a hydroxyl functional acrylic resin. The hydroxyl functional resin can also be, for example, a polyester or a polyurethane.

Suitable volatile blocking agents include for example phenol, cresol, long-aliphatic-chain substituted phenols such as isononylphenol, amides such as ε-caprolactam, active methylene group containing compounds

like malonates such as isopropylidene malonate and acetoacetic esters, sodium bisulfite and oximes such as for example methylethylketone oxime and butanone oxime.

Suitable hydroxyl-functional acrylate resin include for example resins based on hydroxyethyl (meth)acrylate, hydroxypropyl (meth)acrylate and methyl (meth)acrylate. The resin may also be based on methacrylic acid and alkyl esters of (meth)acrylic acid such as methyl acrylate, ethyl (meth)acrylate, isopropyl (meth)acrylate, n-butyl (meth)acrylate, n-propyl (meth)acrylate, isobutyl (meth)acrylate, ethylhexyl acrylate and/or cyclohexyl (meth)acrylate and vinyl compounds such as styrene.

Preferably, the hydroxylacrylate resins have a hydroxyl number between 40 and 150 mg KOH/g resin and an acid number lower than 20 mg KOH/g resin.

The acrylate resins can be prepared by a (co)polymerization, where solvent is fed to a reactor and then heated until the solvent boils. Monomers, and subsequently monomers, initiator and, optionally, mercaptan are added during a period of, for instance, between 2 and 4 hours, after which the temperature is kept at the reflux temperature for, for instance, two hours. The solvent is distilled off by increasing the temperature followed by a vacuum distillation lasting, for instance, one to two hours. Then the product is drained and cooled. Suitable solvents include for example toluene, xylene and butylacetate. Suitable initiators include azo-bis-isobutyronitrile, dibenzoylperoxide and tert.-amyl-peroxy-2-ethyl-hexanoate.

The weight ratio polymer:crosslinker is generally between 90:10 and 50:50.

Preferably the molar equivalent ratio of polymer:crosslinker is between 1:0,8 and 1:1,5. Very suitable ratios are between 1:1 and 1:1,2.

Obviously, all customary additives may be included in the composition. Examples of customary additives include pigments, fillers, flow aids, stabilizers and catalysts. Suitable pigments include

inorganic pigments, for instance titanium oxide, zinc sulphide, iron oxide and chromium oxide, and organic pigments, for instance azo compounds. Suitable fillers include metal oxides, silicates, carbonates and sulphates.

The technology and production of powder coatings is described at pages 224-226 of Powder Coatings, Chemistry and Technology, by Tosko Misev (1991; John Wiley and Sons).

Powder coatings according to the present invention can be applied in general industrial and domestic appliances, metal furnitures, architectural applications, automotive topfinishes, corrosion protective coatings and finishes for wood, plastics and paper.

US-A-5097010 relates to the preparation of thermally-reversible isocyanate polymer by reacting a labile hydrogen segment with an isocyanate segment. The obtained compositions are useful as hot-melt adhesives, coatings and mouldings and furthermore in injection reaction moulding applications and composite and laminate manufacturing followed by thermal forming and pulltrusion. In contrast to the present invention, it is the object of US-A-5097010 to provide a thermally-reversible system. Futhermore in contrast to the present invention, which relates to thermosetting coatings, said US-patent discloses a thermoplastic system with polymer networks which are insoluble strong solids at room temperature but become soluble free flowing melts at high temperature. Of course the polyurethanes are based on diisocyanates and polyols and a man skilled in the art also knows that long flexible polyols result in flexible polymers. The present invention, however, relates to a flexible network and does not relate only to a flexible resin. It is for a man skilled in the art not obvious that a flexible part in a resin will also result in a flexible network. It is the essential feature of the present invention that the poly-tetramethylene ether glycol incorporated in a poly-urethane resin (together with other diols and diiso-cyanates) in combination with an acrylate resin results in

a flexible network. Applying polytetramethylene ether glycol as the glycol alone will not result in a superior powder coating resin. The mixture of polytetramethylene ether glycol with at least one other glycol or polyglycol produces the desired properties. One glycol is responsible for the flexibility, the other glycol is responsible for the level of the glass transition temperature.

The coatings of the present invention are further illustrated by the following experiments and examples. The examples are included for illustrative purposes and should not be considered to limit the present invention.

Experiment I

Synthesis of an hydroxyl functional acrylic resin

A 2 L reactor vessel, equipped with a thermometer, a stirrer and a reflux cooler, was charged with 500 g toluene. The reactor was stirred, a nitrogen flow passed through the reactor and the temperature was increased to reflux temperature. A monomer mixture consisting of 417 g methyl methacrylate (MMA), 175 g hydroxyethyl methacrylate (HEMA), 200 g cyclohexylmethacrylate (CHMA), 200 g n-butylacrylate (BA) and 8 g methacrylic acid (MA) was added. In this monomer mixture 29,4 g 2,2-azo-bis-isobutyronitrile (AIBN) was dissolved.

The monomer mixture was fed to the reactor in 2.5 hours. The reflux temperature was maintained in the reactor for another 2.5 hours. Then a separator vessel was included in the setup, and the solvent was removed by a gradual increase of the temperature and application of a vacuum. A clear product was obtained with a glass transition temperature (Tg, Mettler TA-3000, system 5°C/min) of 46°C and a viscosity (η) (measured with Emila rheometer, 165°C) of 350 dPa.s.

Experiment II

Synthesis of diacetone acrylamide oxime (DAAOX)

100 g diacetone acrylamide was dissolved in 375

ml of distilled water and 45.75 g hydroxylamine hydrochloride was added with stirring. A solution of 43.75 g potassium carbonate in 62.5 ml of distilled water was added at room temperature over a period of 20 min. After the addition was completed, most of the oxime product precipitated. The reaction was continued for an additional hour and the precipitate was filtered and washed with 50 ml of ice water twice. The wet crude product was dissolved in ethylacetate (500 ml), the organic layer was separated and crystallized in the refrigerator. The crystallized product was filtered and washed with 100 ml hexane twice. The final product was dried at 40°C in a vacuum oven to yield 77 g of the DAAOX product. The melting point (112°C) of DAAOX was measured by using a DSC.

Experiment III

The blocking of IPDI with DAAOX (BIPDI)

40.48 g (10% excess) DAAOX obtained according to Experiment I was dissolved in 50 g methylethyl ketone and 22.2 g IPDI was added. The reaction was carried out at room temperature under dry nitrogen. The NCO content was less then 0.1% (by titration) after one hour reaction. The solvent was removed by destillation at 40°C in a vacuum oven overnight. The final blocked IPDI (BIPDI) can be pulverized into fine powder with a melting point of 55-60°C. The blocked NCO content of BIPDI is 13.5% by calculation.

Experiment IV

The blocking of $H_{12}MDI$ with DAAOX (BHMDI)

147.5 g DAAOX (5% excess) obtained according to Experiment I was dissolved in methylethyl ketone (330 g) and 100 g $H_{12}MDI$ was then added. The reaction was carried out at 50°C under dry nitrogen. The NCO content was less then 0.1% (by titration) after one hour of reaction. The solvent was removed at 40°C in a vacuum oven. The final blocked product BHMDI was pulverized to a fine powder and had a melting point (by DSC) of appr. 54°C.

In order to examine the polymerization of BHMDI, the intiator (tert.-amylperbenzoate) was added into BHMDI to initiate polymerization. An exothermic peak was found in the analysis of DSC.

Examples I-VII

Preparation of modified crosslinkers

The glycol blend was made by mixing two glycols in a ratio as mentioned in Table I. In a reactor, equipped with a stirrer and under a stream of dry nitrogen the respective glycol blend and the appropriate amount of HMDI (see Table I) were charged. Methylethylketone (MEK) was added to reduce the viscosity. A small amount of dibutyltindilaurate was added (see Table I) as a catalyst, the reaction mixture was heated to 70°C. It was kept at that temperature until the NCO percentage (as determined by titration) was reduced to half of the initial value. DAAOX was dissolved in MEK and then added into the reaction mixture. The reaction temperature was kept at 70°C until the NCO peak (2270 cm^{-1}) disappeared by checking the infrared spectrum of the product.

After the products in MEK were further diluted with acetone to 25-30% solids content. The dilute solutions were then added dropwise into cold water under vigorous agitation (> 1500 RPM). The precipitates in the powdered form were then filtered and dried. Glass transition temperature and equivalent weights of NCO are given in Table I.

Examples VIII-XIV

Preparation of a powder coating

The powder coating ingredients were weighted (in grammes) in the formulations as showed in Table II. The formulations were dissolved is aceton to prepare a solution of 25-30% solids content. The solutions were added into cold water dropwise under vigorous agitation. The precipitates in powder form were then filtered and dried. The dried powders were ground into a very fine

particle size. They were sprayed electrostatically on plates and cured as showed in Table II.

The present tests are described at pages 296-303 of Powder Coatings by Misev.

Comparative Example A

0.942 g of BHMDI according to Experiment IV was mixed with 2.058 g acrylic resin according to Example I, and the powder mixture was dissolved in 7.5 g of cellosolve acetate. 0.0015 g dibutyltin diacetate was added as a deblocking catalyst. 0.0188 t-amyl-perbenzoate was added as initiator for the polymerization of DAAOX after deblocking reaction. 0.0585 g of E-25™ was added as flow control agent. The solution of this mixture was coated on stell panels, and the panels were baked at 160°C for 30 min. The coatings were well cured, which was proved by the pencil hardness of 2H and more then 200 aceton rubs. However, the impact resistance (ASTM-D-2794) was less than 30 inchpound.

This shows that the coating made with a non-modified crosslinker has poor properties.

The examples show that the isocyanate crosslinker according to the invention results in very flexible acrylic powder coatings with good properties. The claimed invention results in a remarkable increase in impact resistance.

TABLE I (grammes)

	I	II	III	IV	V	VI	VII
HMDI[1)]	262	262	20	20	20	20	20
Voranol[2)]	70,0	89,0	–	–	–	–	–
CHDM[3)]	–	–	4,1	–	–	–	–
Dianol-22[4)]	–	–	–	6,94	–	–	–
Dianol-33[5)]	–	–	–	–	7,28	–	–
1,4-BD[6)]	–	–	–	–	–	2,84	–
NPG[7)]	–	–	–	–	–	–	3,20
Terat 1000[8)]	165,0	–	9,6	16,2	17,0	6,63	7,46
Terat 2000[9)]	–	148,5	–	–	–	–	–
DAAOX[10)]	193,2	193,2	14,75	14,75	14,75	14,75	14,75
DBTL[11)]	0,0738	0,0749	0,0135	0,0173	0,0177	0,0118	0,0123
MEK[12)]	200	200	50	50	50	50	50
Tg (°C)[13)] 45	56	52	n.m.	n.m.	45	46	
NCO equivalent weight	681	684	626	749	764	570	586

HMDI[1)] = Hydrogenated Methylene Diphenyl Diisocyanate
Voranol[2)] = Voranol 220-530 (Dow Chemical); polyether polyol
CHDM[3)] = Cyclohexyldimethanol
Dianol-22[4)] = 2,2-bis(1-hydroxy-2-oxy-ethylphenyl)propane
Dianol-33[5)] = 1,1-isopropylidene-bis(p-phenyleneoxy)-di-2-propanol-2
1,4-BD[6)] = 1,4-butanediol
NPG[7)] = Neopentylglycol
Terat 1000[8)] = Terathane 1000 (Du Pont): polytetramethylene ether glycol with molecular weight 1000
Terat 2000[9)] = Terathane 2000 (Du Pont): polytetramethylene ether glycol with molecular weight 2000
DAAOX[10)] = See Experiment II
DBTL[11)] = Dibutyltindilaurate
MEK[12)] = Methylethylketone
Tg (°C)[13)] = Glass transition point; n.m.= not measured

TABLE II

	VIII	IX	X	XI	XII	XIII	XIV
Resin Exp. I	100	100	100	100	100	100	100
Crosslinker I	105,3	–	–	–	–	–	–
Crosslinker II	–	105,8	–	–	–	–	–
Crosslinker III	–	–	96,85	–	–	–	–
Crosslinker IV	–	–	–	111,0	–	–	–
Crosslinker V	–	–	–	–	113,1	–	–
Crosslinker VI	–	–	–	–	–	80,61	–
Crosslinker VII	–	–	–	–	–	–	82,82
TI[1]	2,053	2,058	1,968	2,110	2,131	1,806	1,828
TAP[2]	1,053	1,058	0,9685	1,110	1,131	0,806	0,828
E^{25} [3]	2,669	2,075	2,559	2,743	2,770	2,348	2,377
Cure conditions	150°C 30′	150°C 30′	150°C 30′	150°C 30′	150°C 30′	150°C 30′	150°C 30′
Hardness[4]	> H	> H	2H	> H	> H	> H	> H
Aceton res.[5]	> 200	> 200	> 200	> 200	> 200	> 200	> 200
Impact res.[6]							
– direct	120	110	110	> 160	> 160	> 160	140
– reverse	100	60	< 60	> 160	> 160	> 160	120

TI[1] = Dibutyltin diacetate
TAP[2] = Tert. amyl perbenzoate
E^{25} [3] = Flow control agent (DSM)
Hardness[4] = Pencil hardness (ASTM-D-3363)
Aceton res.[5] = Acetone resistance (solvent cure test method)
Impact res.[6] = Impact resistance (ASTM-D-2794)

CLAIMS

1. A powder paint based on acrylics, characterized in that, the thermosetting powder paint comprises
- a hydroxyl functional acrylic resin and
- an isocyanate crosslinking agent blocked with a blocking agent, wherein the isocyanate crosslinking agent is an adduct of an isocyanate and a mixture of polytetramethylene ether glycol and at least one additional, but other glycol, selected from the group consisting of glycols and polyglycols.
2. Powder paint according to claim 1, characterized in that the additional polyglycol is a polyether polyol.
3. Powder paint according to any one of claims 1-2, characterized in that the blocking agent is an agent having a polymerisable double bond and an oxime-function.
4. Powder paint according to claim 3, characterized in that the agent is diacetone acrylamide oxime.
5. Use of an adduct of an isocyanate and a mixture of polytetramethylene ether glycol and at least one additional but other glycol selected from the group consisting of glycols and polyglycols as crosslinking agent in the preparation of powder coatings.
6. A method for preparing a powder paint composition comprising a hydroxyl functional acrylic resin and an isocyanate crosslinking agent which is blocked, characterized in that the isocyanate crosslinking agent comprises an adduct of an isocyanate and a mixture of polytetramethylene ether glycol and at least one additional, but other glycol selected from the group consisting of glycols and polyglycols and the weight ratio of polymer:crosslinking agent is between 90:10 and 50:50.
7. Method according to claim 6, characterized in that the blocking agent is an agent having a polymerisable double bond and an oxime-function.

8. Method according to claim 7, characterized in that the agent is diacetone acrylamide oxime.

9. Binder composition comprising a resin and a crosslinking agent characterized in that the resin is a hydroxyl functional acrylic resin and the crosslinking agent an isocyanate crosslinking agent blocked with a blocking agent, wherein the isocyanate crosslinking agent is an adduct of an isocyanate and a mixture of polytetramethylene ether glycol and at least one additional, but other glycol, selected from the group consisting of glycols and polyglycols.

10. Binder composition comprising a hydroxyl group containing polymer and an isocyanate crosslinking agent blocked with a blocking agent, characterized in that the blocking agent is an agent having a polymerizable double bond and an oxime-function.

11. Powder paint composition comprising a hydroxyl group containing polymer and an isocyanate crosslinking agent blocked with a blocking agent, characterized in that the blocking agent is an agent having a polymerizable double bond and an oxime-function.

12. An article coated with a composition according to any one of claims 1-4 or an article coated with a composition obtained according to any one of claims 6-8.

INTERNATIONAL SEARCH REPORT

Inten nal Application No
PCT/NL 93/00212

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 C08G18/12 C08G18/28 C08G18/62 C08G18/66 C08G18/40
C08G18/48 C08G18/67 C08G18/81 C09D5/03 C09D175/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 C08G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR,A,2 568 884 (STEVENS-GENIN) 14 February 1986 see claims 1-3 see page 1, line 1 - line 4 see page 4, line 16 - line 27 ---	1
A	EP,A,0 327 031 (ASAHI KASEI) 9 August 1989 see claims 1,7,9 -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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1

Date of the actual completion of the international search	Date of mailing of the international search report
4 February 1994	24.02.94
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Information on patent family members

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